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A COMPARISON OF CONCRETE SCALING CAUSED BY CALCIUM MAGNESIUM ACETATE AND SODIUM CHLORIDE IN LABORATORY TESTS

MATERIALS INFORMATION
ENGINEERING MATERIALS OFFICE

A COMPARISON OF CONCRETE SCALING CAUSED BY CALCIUM MAGNESIUM ACETATE AND SODIUM CHLORIDE IN LABORATORY TESTS

BY

F. PIANCA
RESEARCH AND DEVELOPMENT BRANCH

K. CARTER
H. SEDLAK
CONCRETE SECTION
ENGINEERING MATERIALS OFFICE

ONTARIO MINISTRY OF TRANSPORTATION AND COMMUNICATIONS

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ABSTRACT

This report describes a series of salt scaling tests using sodium chloride and calcium magnesium acetate (CMA) on typical concrete mixes used in Ontario. Good quality concrete was resistant to scaling by both types of deicing salt. With poorer quality concrete CMA caused much less salt scaling damage than sodium chloride.

INTRODUCTION

Public demand for safer driving conditions in winter has led to the use of large quantities of deicing chemicals to keep pavements free of ice and snow. The most commonly used chemical, sodium chloride, causes corrosion of vehicles, environmental damage, and damage to bridges. With concrete bridges the damage is caused by increased corrosion of the reinforcing steel leading to concrete spalling, and damage to the concrete itself which is usually called salt scaling.

The search for a less damaging deicing salt has led to investigation of calcium magnesium acetate (CMA). Reports 1, 2, 3 have shown that CMA is a reasonably effective deicer although it is presently much more expensive than sodium chloride. It appears to be less corrosive and more environmentally desirable than sodium chloride, but little is known about its potential to damage concrete by salt scaling.

This report gives details of a laboratory test program to compare the relative salt scaling damage caused by CMA and sodium chloride in standard salt scaling tests on a number of typical concrete mixes used by the Ontario Ministry of Transportation and Communications (M.T.C.).

TEST PROGRAM

Fifteen different concrete mixes were used in the test program. The concrete was made from typical materials used in M.T.C. concrete and the proportions were varied to give a range of salt scaling resistance from excellent to very poor. The most resistant mixes were typical 30 MPa class mixes, air entrained with a water reducing admixture and a low water cement ratio, or latex modified mixes. Less resistant mixes were made by increasing the water cement ratio and by leaving out the admixture and air entraining agent. The materials used are listed below.

Cements — Type 10 cement from one source was used in twelve mixes and Type 10 cement from a second source in three mixes. In two mixes a blend of 25% slag cement was used.

Aggregates — Ten mixes used a 19 mm crushed dolomite limestone coarse aggregate from the Niagara Escarpment. Three mixes used typical partly crushed mixed gravel coarse aggregate, and two mixes used a traprock coarse aggregate. The fine aggregates were two different sand sources.

Admixtures — The air entraining admixture was a sulphonated hydrocarbon type (OPSS 1303, ASTM C260). The water reducing admixture was a lignosulphonate normal setting admixture (OPSS 1303, Type WN, ASTM C494, Type A). Two different latexes of the styrene-butadiene type were used.

Deicers — The sodium chloride was typical road salt used in Ontario. The CMA was supplied from a commercial source and had a 1:1 Ca:Mg mole ratio.

Table 1 lists the materials and the proportions used in each of the fifteen mixes. Table 2 lists the test results on the fresh concrete. Eight concrete slabs, 300 mm x 300 mm x 75 mm were made from each mix. Four slabs were made from each single batch of concrete and for testing purposes a pair of slabs consisted of one slab from each of the two batches. Curing consisted of standard moist curing for 14 days followed by 14 days of dry curing. A dyke was formed in the top of each slab to hold the ponded deicer. The proportions of deicer used by weight and the approximate pH levels of the solutions were as follows:

Deicer	pH
3% NaCl	8.3
2% CMA	8.0
4% CMA	8.6
6% CMA	9.1

Two slabs were used for each deicer concentration. The slabs were subjected to 50 cycles of freezing and thawing. After every 5 cycles the material scaling from the surface of the concrete was removed and weighed. The

TABLE NO. 1

DESIGN MIX PROPORTIONS (kg/m^3)

MIX NO.	CLASS MPa	CEMENT SOURCE 1	CEMENT SOURCE 2	SLAG	COARSE AGGREGATE CRUSHED LIMESTONE	COARSE AGGREGATE GRAVEL	COARSE AGGREGATE TRAPROCK	FINE AGGREGATE SOURCE 1	FINE AGGREGATE SOURCE 2	WATER	LATEX	ADMIXTURE (ml) WATER REDUCING AGENT	ADMIXTURE (ml) AIR ENTRAINING AGENT
1	30	356			1084			742		157		1565	71
2	30	356			1084			742		160		1565	
3	20	310			1084			783		158		1365	49
4	20	310			1084			783		158		1365	
5	20	310			1084			837		180			
6	20		310		1084			783		155			
7	20		310		1084			783		167			
8	30	356				1166			674	142		1565	95
9	30	356				1166			674	146		1565	69
10	20	310				1166			761	146		1365	
11	30	391					840	916		52	122		
12	30	391			772			910		62	122		
13	20	234		76	1084			783		146		1365	73
14	20	234		76	1084			783		153		1379	19
15	30		391				940	391		62	122		

TABLE NO. 2

TEST RESULTS FRESH CONCRETE

MIX NO.	CLASS MPa	SLUMP mm		AIR CONTENT %		CEMENT FACTOR kg/m^3		EFFECTIVE W/C RATIO	
		BATCH		BATCH		BATCH		BATCH	
		1	2	1	2	1	2	1	2
1	30	80	85	6.2	5.8	353.1	355.0	0.44	0.44
2	30	80	85	3.7	3.9	360.9	359.9	0.45	0.45
3	20	80	85	6.5	6.5	307.3	307.3	0.51	0.51
4	20	90	85	4.0	4.0	316.7	317.5	0.51	0.51
5	20	80	85	1.8	2.5	310.7	310.7	0.58	0.58
6	20	85	70	6.0	5.4	311.7	315.0	0.50	0.50
7	20	90	85	4.4	3.8	313.4	315.3	0.54	0.54
8	30	85	90	6.2	6.4	352.2	352.2	0.40	0.40
9	30	80	85	3.1	3.9	364.9	361.7	0.41	0.41
10	20	80	70	3.3	3.5	311.5	311.5	0.47	0.47
11	30	210	215	4.4	4.6	429.9	424.8	0.29	0.28
12	30	220	210	4.7	4.8	432.4	431.1	0.31	0.31
13	20	80	80	6.0	5.9	308.9	309.8	0.47	0.47
14	20	80	75	4.2	3.8	316.7	318.4	0.49	0.48
15	30	140	150	2.8	2.7	433.7	433.5	0.31	0.31

cumulative average weight loss for each pair of slabs is listed in Tables 3A, 3B and 3C.

Full details of the test procedures used are given in the appendix.

DISCUSSION OF RESULTS

The loss of mass for each mix and each deicing solution are shown on Figure 1. Concrete mixes which show scaling losses less than 0.8 kg/m^2 after 50 cycles are generally considered by the M.T.C. to be resistant to salt scaling. Nine mixes scaled less than 0.8 kg/m^2 with sodium chloride (Mix #1, 2, 3, 6, 8, 9, 11, 12 and 15). With these mixes the 6% CMA solution caused about the same amount of scaling as the 3% sodium chloride. Generally the weaker solutions of CMA caused less scaling.

With the less resistant mixes the sodium chloride caused much more scaling than the CMA. The scaling caused by the CMA varied with the strength of the solution but no clear trends were establaished. With five of the six mixes the scaling caused by sodium chloride was above 0.8 kg/m^2 whereas the average scaling caused by the CMA on the same five mixes was less than 0.8 kg/m^2.

CONCLUSIONS

1. Good quality concrete mixes are resistant to scaling by both sodium chloride and CMA.

2. Mixes which show a tendency to scale with sodium chloride show much less scaling with CMA.

3. CMA could be used for deicing in winter maintenance operations in Ontario with no fear of its increasing the general level of scaling damage to portland cement concrete. In many cases its use may reduce the chance of scaling damage.

TABLE NO. 3A

SALT SCALING TEST RESULTS (MASS LOSS kg/m^2)

MIX NO.	1
CLASS	30 MPa
COARSE AGG.	LIMESTONE
CEMENT (SOURCE	1
AIR CONTENT %	6.0

CYCLES	5	10	15	20	25	30	35	40	45	***50***
3%NACL	0.029	0.055	0.060	0.064	0.100	0.137	0.148	0.162	0.184	**0.241**
2%CMA	0.019	0.033	0.037	0.044	0.082	0.135	0.174	0.194	0.208	**0.218**
4%CMA	0.016	0.028	0.035	0.042	0.063	0.102	0.138	0.165	0.185	**0.215**
6%CMA	0.029	0.045	0.059	0.066	0.099	0.136	0.161	0.178	0.227	**0.249**

MIX NO.	2
CLASS	30 MPa
COARSE AGG.	LIMESTONE
CEMENT (SOURCE	1
AIR CONTENT %	3.8

CYCLES	5	10	15	20	25	30	35	40	45	***50***
3%NACL	0.054	0.119	0.135	0.152	0.184	0.218	0.242	0.257	0.266	**0.282**
2%CMA	0.026	0.033	0.037	0.048	0.069	0.090	0.102	0.118	0.125	**0.132**
4%CMA	0.020	0.031	0.039	0.042	0.054	0.079	0.097	0.110	0.143	**0.160**
6%CMA	0.014	0.035	0.050	0.058	0.100	0.133	0.156	0.180	0.209	**0.231**

MIX NO.	3
CLASS	20 MPa
COARSE AGG.	LIMESTONE
CEMENT (SOURCE	1
AIR CONTENT %	6.5

CYCLES	5	10	15	20	25	30	35	40	45	***50***
3%NACL	0.051	0.086	0.099	0.120	0.179	0.242	0.280	0.354	0.395	**0.445**
2%CMA	0.023	0.042	0.062	0.075	0.122	0.177	0.213	0.237	0.255	**0.271**
4%CMA	0.040	0.063	0.078	0.090	0.115	0.138	0.183	0.226	0.252	**0.273**
6%CMA	0.060	0.089	0.120	0.154	0.203	0.272	0.300	0.351	0.379	**0.412**

MIX NO.	4
CLASS	20 MPa
COARSE AGG.	LIMESTONE
CEMENT (SOURCE	1
AIR CONTENT %	4.0

CYCLES	5	10	15	20	25	30	35	40	45	***50***
3%NACL	0.392	0.542	0.639	0.697	0.770	0.863	0.966	1.070	1.140	**1.264**
2%CMA	0.150	0.209	0.245	0.270	0.335	0.424	0.493	0.545	0.570	**0.587**
4%CMA	0.037	0.086	0.107	0.134	0.169	0.226	0.285	0.347	0.397	**0.425**
6%CMA	0.493	0.569	0.595	0.634	0.683	0.730	0.799	0.850	0.872	**0.895**

MIX NO.	5
CLASS	20 MPa
COARSE AGG.	LIMESTONE
CEMENT (SOURCE	1
AIR CONTENT %	2.2

CYCLES	5	10	15	20	25	30	35	40	45	***50***
3%NACL	1.753	3.435	5.414	7.541	10.428	**DISCONTINUED**				
2%CMA	0.164	0.320	0.521	0.683	0.874	1.034	1.140	1.206	1.265	**1.302**
4%CMA	0.044	0.176	0.351	0.548	0.730	0.932	1.099	1.178	1.245	**1.853**
6%CMA	0.018	0.070	0.145	0.197	0.289	0.452	0.570	0.674	0.729	**0.808**

TABLE NO. 3B

SALT SCALING TEST RESULTS (MASS LOSS kg/m^2)

MIX NO.	6
CLASS	20 MPa
COARSE AGG.	LIMESTONE
CEMENT (SOURCE	2
AIR CONTENT %	5.7

CYCLES	5	10	15	20	25	30	35	40	45	***50***
3%NACL	0.028	0.075	0.096	0.115	0.137	0.159	0.191	0.224	0.251	**0.279**
2%CMA	0.035	0.052	0.076	0.107	0.155	0.210	0.252	0.286	0.317	**0.328**
4%CMA	0.024	0.042	0.062	0.082	0.126	0.208	0.277	0.313	0.333	**0.347**
6%CMA	0.011	0.045	0.083	0.098	0.143	0.216	0.258	0.291	0.312	**0.336**

MIX NO.	7
CLASS	20 MPa
COARSE AGG.	LIMESTONE
CEMENT (SOURCE	2
AIR CONTENT %	4.1

CYCLES	5	10	15	20	25	30	35	40	45	***50***
3%NACL	0.133	0.270	0.383	0.477	0.532	0.595	0.611	0.754	0.886	**0.985**
2%CMA	0.114	0.186	0.234	0.287	0.318	0.374	0.377	0.453	0.505	**0.565**
4%CMA	0.047	0.094	0.132	0.149	0.168	0.214	0.231	0.328	0.417	**0.463**
6%CMA	0.030	0.077	0.102	0.161	0.220	0.257	0.297	0.351	0.396	**0.449**

MIX NO.	8
CLASS	30 MPa
COARSE AGG.	GRAVEL
CEMENT (SOURCE	1
AIR CONTENT %	6.3

CYCLES	5	10	15	20	25	30	35	40	45	***50***
3%NACL	0.044	0.069	0.086	0.100	0.119	0.140	0.246	0.263	0.273	**0.287**
2%CMA	0.033	0.044	0.054	0.062	0.075	0.086	0.144	0.149	0.153	**0.157**
4%CMA	0.016	0.030	0.039	0.051	0.064	0.079	0.116	0.120	0.125	**0.125**
6%CMA	0.028	0.049	0.073	0.091	0.106	0.128	0.183	0.193	0.202	**0.202**

MIX NO.	9
CLASS	30 MPa
COARSE AGG.	GRAVEL
CEMENT (SOURCE	1
AIR CONTENT %	3.5

CYCLES	5	10	15	20	25	30	35	40	45	***50***
3%NACL	0.059	0.112	0.165	0.214	0.267	0.297	0.320	0.346	0.396	**0.435**
2%CMA	0.018	0.051	0.059	0.064	0.071	0.074	0.078	0.083	0.094	**0.099**
4%CMA	0.026	0.045	0.053	0.064	0.070	0.072	0.074	0.085	0.091	**0.095**
6%CMA	0.026	0.062	0.088	0.103	0.122	0 134	0.146	0.164	0.193	**0.224**

MIX NO.	10
CLASS	20 MPa
COARSE AGG.	GRAVEL
CEMENT (SOURCE	1
AIR CONTENT %	3.4

CYCLES	5	10	15	20	25	30	35	40	45	***50***
3%NACL	0.047	0.337	0.498	0.731	0.921	1.032	1.131	1.254	1.416	**1.543**
2%CMA	0.051	0.136	0.238	0.308	0.370	0.427	0.482	0.529	0.565	**0.600**
4%CMA	0.022	0.085	0.292	0.391	0.454	0.500	0.544	0.580	0.605	**0.628**
6%CMA	0.030	0.068	0.092	0.130	0.193	0.262	0.332	0.387	0.468	**0.499**

TABLE NO. 3C

SALT SCALING TEST RESULTS (MASS LOSS kg/m^2)

MIX NO.	11
CLASS	30 MPa
COARSE AGG.	TRAPROCK
CEMENT (SOURCE	1
AIR CONTENT %	4.5

CYCLES	5	10	15	20	25	30	35	40	45	50
3%NACL	0.017	0.021	0.047	0.058	0.079	0.092	0.106	0.135	0.155	0.172
2%CMA	0.005	0.010	0.014	0.016	0.021	0.023	0.025	0.035	0.037	0.051
4%CMA	0.007	0.011	0.019	0.039	0.046	0.048	0.054	0.071	0.083	0.091
6%CMA	0.013	0.035	0.064	0.093	0.121	0.137	0.150	0.191	0.200	0.225

MIX NO.	12
CLASS	30 MPa
COARSE AGG.	LIMESTONE
CEMENT (SOURCE	1
AIR CONTENT %	4.8

CYCLES	5	10	15	20	25	30	35	40	45	50
3%NACL	0.006	0.007	0.015	0.025	0.039	0.049	0.058	0.065	0.069	0.076
2%CMA	0.002	0.006	0.010	0.012	0.022	0.023	0.025	0.032	0.034	0.044
4%CMA	0.002	0.005	0.030	0.035	0.045	0.050	0.054	0.072	0.078	0.101
6%CMA	0.013	0.025	0.048	0.066	0.081	0.093	0.108	0.127	0.174	0.194

MIX NO.	13
CLASS	20 MPa
COARSE AGG.	LIMESTONE
CEMENT (SOURCE	1
AIR CONTENT %	6

CYCLES	5	10	15	20	25	30	35	40	45	50
3%NACL	0.949	1.230	1.394	1.580	1.630	1.787	1.844	1.986	2.116	2.185
2%CMA	0.066	0.161	0.226	0.287	0.314	0.369	0.391	0.410	0.442	0.455
4%CMA	0.102	0.167	0.250	0.340	0.393	0.468	0.505	0.550	0.594	0.622
6%CMA	0.044	0.119	0.213	0.319	0.372	0.525	0.575	0.638	0.707	0.756

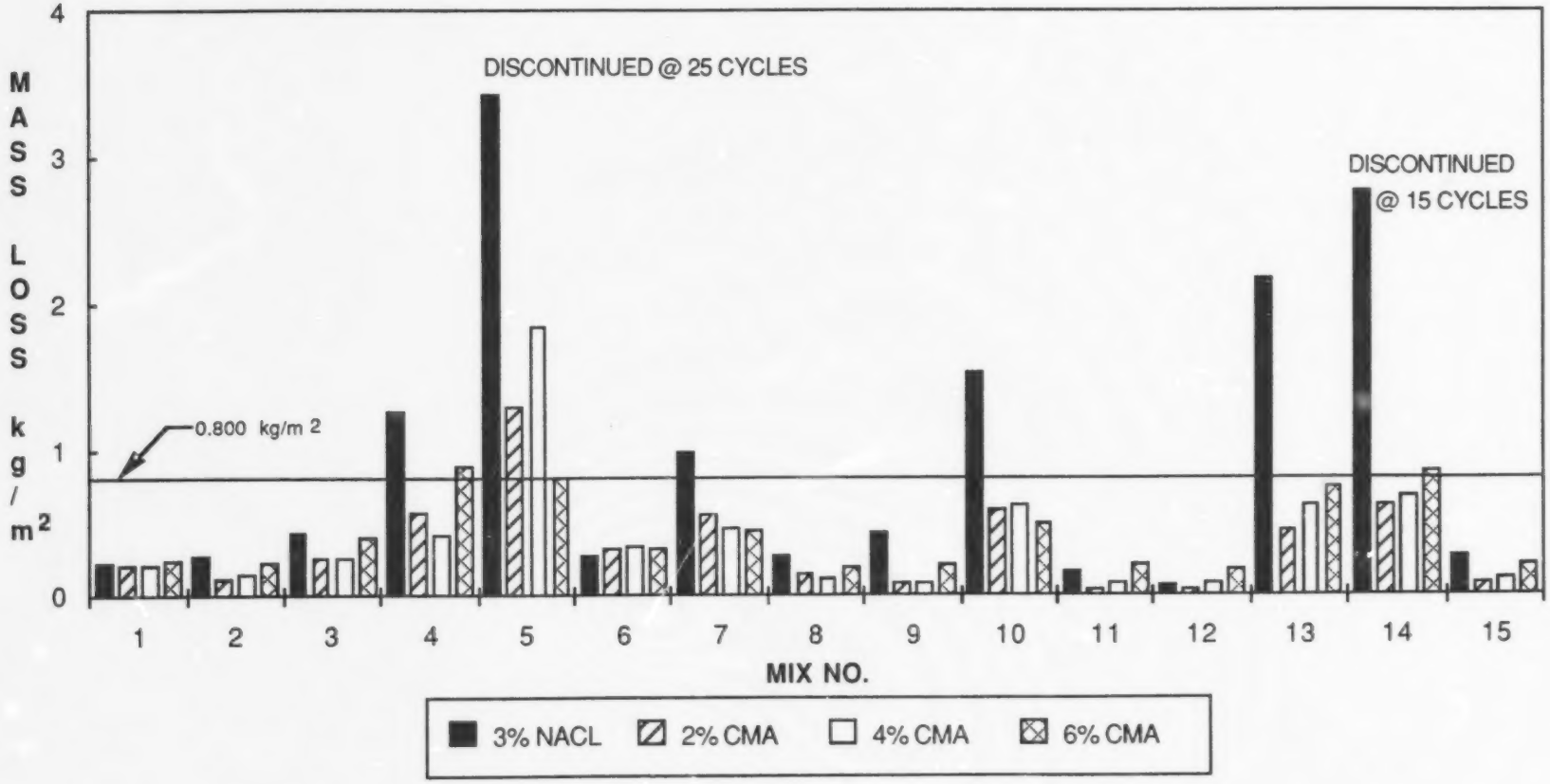
MIX NO.	14
CLASS	20 MPa
COARSE AGG.	LIMESTONE
CEMENT (SOURCE	1
AIR CONTENT %	4

CYCLES	5	10	15	20	25	30	35	40	45	50
3%NACL	0.861	2.775	3.348	DISCONTINUED						
2%CMA	0.242	0.373	0.443	0.487	0.505	0.545	0.563	0.577	0.607	0.620
4%CMA	0.195	0.353	0.450	0.501	0.536	0.583	0.609	0.640	0.677	0.694
6%CMA	0.105	0.194	0.326	0.465	0.550	0.650	0.709	0.760	0.802	0.861

MIX NO.	15
CLASS	30 MPa
COARSE AGG.	TRAPROCK
CEMENT (SOURCE	2
AIR CONTENT %	2.8

CYCLES	5	10	15	20	25	30	35	40	45	50
3%NACL	0.016	0.038	0.058	0.078	0.104	0.107	0.138	0.177	0.217	0.286
2%CMA	0.009	0.019	0.032	0.046	0.053	0.053	0.057	0.070	0.083	0.089
4%CMA	0.019	0.028	0.051	0.068	0.079	0.082	0.091	0.108	0.121	0.129
6%CMA	0.031	0.058	0.100	0.115	0.149	0.156	0.166	0.182	0.204	0.213

FIGURE NO. 1


DISCONTINUED @ 25 CYCLES
DISCONTINUED
@ 15 CYCLES
0.800 kg/m 2
MASS LOSS kg/m2
MIX NO.
3% NACL
2% CMA
4% CMA
6% CMA

REFERENCES

1. Dunn, S. A. and Schenk, R. V., "Alternative Highway Deicing Chemicals", prepared for Federal Highway Administration, Report No. FHWA-RD-79-109, 1980.

2. Chollar, B. H., FCP Annual Progress Report - Year Ending September 30, 1984, on Project "Calcium Magnesium Acetate (CMA) as an Alternate Deicer", Federal Highway Administration, 1984.

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APPENDIX

Method of Test for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals

METHOD OF TEST
FOR SCALING RESISTANCE OF CONCRETE SURFACES EXPOSED TO DEICING CHEMICALS

1. SCOPE

1.1 This test method covers determination of the resistance to scaling of a horizontal concrete surface exposed to freezing and thawing cycles in the presence of deicing chemicals. It is intended for use in evaluating this surface resistance quantitatively by determining the dry mass of the flaked off concrete and qualitatively by visual examination.

2. RELEVANT DOCUMENTS

2.1 ASTM Designation C 192

2.2 ASTM Designation C 672

2.3 OPSS 1351

2.4 MTC Laboratory Testing Manual, Volume I

3. DEFINITION

3.1 Scaling is flaking or peeling away of the near surface portion of hardened concrete or mortar, or a thin layer of mortar flakes off the surface of coarse aggregate.

4. SIGNIFICANCE AND USE

4.1 This test method can be used to evaluate the effect of mix proportions, surface treatment, curing, or other variables on resistance to scaling.

4.2 This test method is also used to evaluate salt scaling resistance of slabs cut from hardened concrete such as barrier walls, precast manholes and noise barriers.

5. APPARATUS

5.1 FREEZING EQUIPMENT: A cabinet or room of sufficient size to hold specimens and capable of lowering the temperature of the specimens to $-18 \pm 2^{\circ}C$ within 16 to 18 hours and maintaining this temperature with a full load of specimens.

5.2 THAWING ROOM: A room or cabinet maintaining an air temperature of $23 \pm 2^{\circ}C$ and a relative humidity of $50 \pm 5\%$.

...2/-

5.3 SCALES: Scales for determining mass of batches of materials and concrete shall conform to the requirements of MTC Test Method LS-401.

5.4 BALANCE: A balance or scale having a minimum capacity of 5000 g and an accuracy of 0.1 g.

5.5 CONCRETE MIXER: A mixer complying with the requirements of MTC Test Method LS-401.

5.6 SLUMP CONE AND AIR METER: The apparatus shall comply with the requirements of MTC Test Method LS-402 and LS-403 (or LS-404), respectively.

5.7 MOULDS: Moulds shall be 300 x 300 x 75 mm in inside dimensions and have collars attached to form ledges for the installation of a precast dyke. They shall conform to the requirements of ASTM C 192. Moulds made of 19 mm thick plywood are acceptable provided that they are waterproofed to make them non-absorptive and leakproof.

5.8 TAMPING ROD: A round straight steel rod 16 mm in diameter and approximately 600 mm in length, having the tamping end rounded to a hemispherical tip of the same diameter as the rod.

5.9 DRYING OVEN: An oven capable of maintaining a temperature of 105 ± 2°C.

5.10 FILTER PAPER: Whatman No. 2, 320 mm in diameter or equivalent.

5.11 SMALL TOOLS: Wood strike-off board, 75 mm paint brush to provide the desired texture of the test surface, and a polyethylene sheet 350 x 350 mm, mounted on a plywood frame to cover the plastic concrete prior to placing in the moisture room.

6. PROPORTIONING AND MIXING

6.1 PROPORTIONING: The air content, cement content, water cement ratio, slump and other characteristics of the concrete and its ingredients shall be those appropriate for the purposes for which the tests are to be made.

6.2 MIXING: The mixing shall be in accordance with MTC Test Method LS-401.

6.3 TESTING PLASTIC CONCRETE: All the standard tests shall be carried out in accordance with MTC Test Method LS-401.

7. SPECIMENS

7.1 NUMBER OF SPECIMENS: At least two duplicate specimens, each 300 x 300 x 75 mm, shall be made for each test condition.

...3/-

7.2 FABRICATION OF SPECIMENS: Coat the inside surface of each mould with a light film of form oil just prior to fabrication of the specimens. Fill the mould in one layer and rod one time for each 1300 mm2 of surface (300 x 300 mm area requires 70 strikes of the rod), leaving a slight excess of material after the final rodding. Tap around the mould perimeter with a nylon tipped hammer to close any remaining voids and immediately screed excess concrete with a wood strike-off board and finish the surface with two passes of a wood float, one in each direction. After the concrete has stopped bleeding, finish the surface with three sawing-motion passes of a wood strike-off board. Brush the surface with a mediuim stiff brush as a final finishing operation to remove any laitance and to leave a slightly textured surface unless another method of surface finishing is to be evaluated.

7.3 SPECIMENS FROM HARDENED CONCRETE: Slabs obtained from hardened concrete shall have a test area approximately equal to the area of the cast specimens (7.1). The surface to be tested shall be free of any damage.

8. CURING AND DYKING

8.1 LABORATORY CAST SPECIMENS: Immediately after finishing the surface (7.2), cover the surface with a polyethylene sheet (5.11) and move the specimens into moist storage (23 ± 2°C, at least 95% R.H.). At 20 to 24 h after addition of water to the mix, remove the specimens from the moist storage, demould, identify each and return them to the moist storage. Remove the specimens from the moist storage at the age of 14 d and place them in air for 14 d at 23 ± 2°C and a relative humidity of 45-55%. During the dry storage period, apply an air entrained paste to the recessed ledges around the perimeter of the test specimen, then lower a precast air entrained mortar dyke into the recess (Fig. 1) and remove any excess paste. After allowing the paste to harden for 24 h, apply epoxy sealant to the inside, top and outside of the dyke extending the outside surface epoxy treatment to 25 mm below the joint.

8.2 SPECIMENS FROM HARDENED CONCRETE: Apply an epoxy bonding agent around the perimeter of the top surface of each specimen and cast a 20 x 20 mm epoxy mortar dyke, (Fig. 2). Allow the dyke to cure for 3 d at 23 ± 2°C and 45-55% relative humidity before starting the salt scaling test.

...4/-

9. TEST PROCEDURE

9.1 SALT SOLUTION: The deicing salt shall be a 3% solution of sodium chloride. The test surface shall be covered with approximately 6 mm of the solution.

9.2 FREEZE-THAW CYCLE: At the age of 28 d, cover the test surface with the salt solution and expose the specimens to continuous freeze-thaw cycling, each cycle consisting of 16-18 h in the freezing environment followed by storage at 23 ± 2°C and a relative humidity of 45-55% for 6-8 h. Add the salt solution before each freezing phase of the cycle as necessary to maintain the required depth.

During the test each specimen shall be supported by means of wood strips, to allow free air circulation under, around and over it (Fig. 1).

9.10 MASS LOSS: After each 5 cycles, remove the salt solution together with all the flaked off concrete from the surface and place into a watertight container. The operation is best accomplished by tilting the slab into a funnel approximately 500 mm in diameter and washing the surface of the specimen with the salt solution. The washing should continue until all loose particles are removed from the concrete. The solution shall then be strained through a filter and the residue dried out in an oven at 105°C to a constant mass condition. The residue shall be cumulatively weighed after each 5 cycles. This residue shall be defined as the loss of mass and expressed in kilograms per square metre of exposed slab area. The loss of mass shall be calculated to the nearest 0.01 kg/m2.

After the washing of each slab, the surface shall be covered with a new solution of sodium chloride.

9.11 VISUAL RATING OF SURFACE: After each 5 cycles, rate the test surface of each specimen in accordance with the following scale:

Rating	Condition of Surface
0	No scaling.
1	Very slight scaling (3 mm depth max., no coarse aggregate visible).
2	Slight to moderate scaling.
3	Moderate scaling (some coarse aggregate visible).
4	Moderate to severe scaling.
5	Severe scaling (coarse aggregate visible over entire surface).

...5/-

9.12 NUMBER OF CYCLES: Unless otherwise stated in the test program, terminate the test after exposure to 50 cycles.

10. **REPORT**

The report shall include the following:

10.1 Specimens fabricated in the laboratory.

- mix proportions
- source and type of each concrete ingredient
- slump and air content
- curing of specimens if other than standard
- area of the surface exposed to scaling (each slab)
- cumulative mass loss after each 5 cycles (each slab)
- visual rating of the surface after each 5 cycles (each slab)
- photographs of each slab at 0, 10, 25 and 50 cycles (if test is extended, photographs also required at completion of test)

10.2 Specimens from Hardened Concrete

- the size and shape of the specimen
- orientation of the specimen in the structure
- curing if other than standard
- area of the surface exposed to scaling (each slab)
- cumulative mass loss after each 5 cycles (each slab)
- visual rating of the surface after each 5 cycles (each slab)
- photographs of each slab at 0, 10, 25 and 50 cycles (if test is extended, photographs also required at completion of test)

...6/

11. GENERAL NOTES

11.1 If the method is used to evaluate a concrete coating or penetrating sealant, the sealant shall be applied during the dry storage period at the time and in the manner specified by the test program for the sealant. The treated specimens shall be exposed to the cycling at the time required by the test program.

11.2 Curing of the specimens may differ from the standard depending on the mix, e.g. latex mix. In such cases, the specimens are cured as required by the test program.

11.3 If there is any interruption in the daily cycling, the specimens shall be kept frozen.

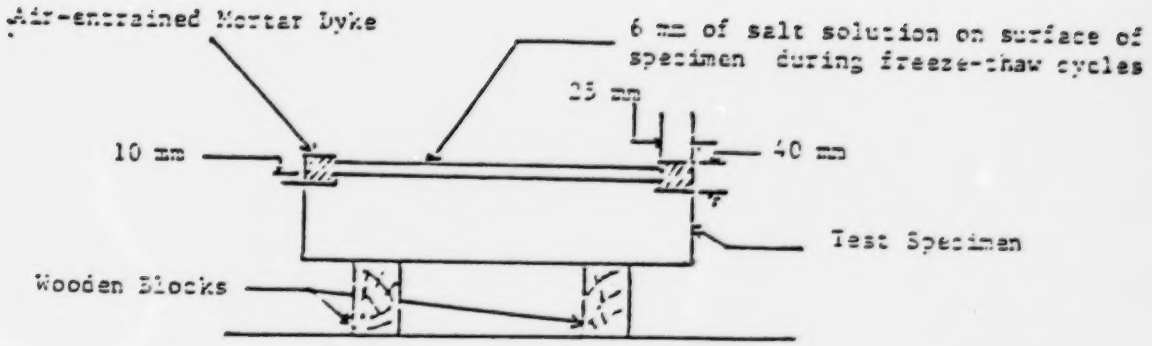
Air-entrained Mortar Dyke
6 mm of salt solution on surface of specimen during freeze-thaw cycles
25 mm
10 mm
40 mm
Test Specimen
Wooden Blocks

Fig. 1

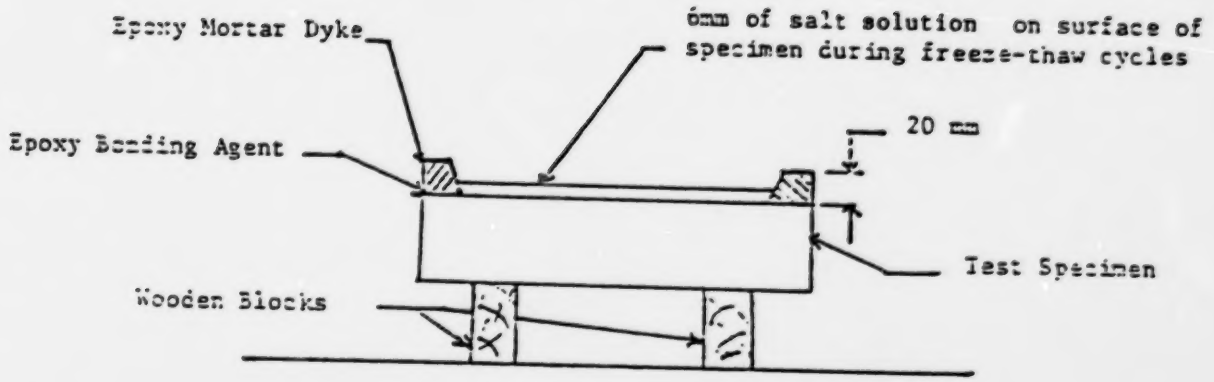
Epoxy Mortar Dyke
6mm of salt solution on surface of specimen during freeze-thaw cycles
Epoxy Bonding Agent
20 mm
Test Specimen
Wooden Blocks

Fig. 2